Dredging Research Technical Notes

Field Test of the Dredging Research Program (DRP) Eductor

Purpose

This technical note describes the field test conducted and results of the comparative performance analysis for two sand bypass eductors. The existing Indian River Inlet (IRI), Delaware, eductor and a new design (the DRP eductor) were compared to evaluate relative performance to determine what, if any, production differences may exist in routine bypass operations.

Background

Fixed sand bypass plants have been used in the United States since the 1930s (Jones and Mehta 1980), though their designs were based on conventional hydraulic dredge systems (Watts 1962). During the late 1970s and the 1980s a limited number of eductor (or jet pump) based bypass plants operated on the U.S. east and Gulf coasts. These plants experienced limited effectiveness, primarily because debris problems reduced production and there were difficulties in deploying and retrieving eductors. In 1986 a large bypass plant was constructed at the Nerang River Entrance in Southport, Queensland, Australia (Clausner 1988). This plant uses 10 eductors spaced at 100-ft intervals along a pier extending through the surf zone, and has effectively bypassed large quantities of sand (in excess of 500,000 cu yd/year). However, even in this innovative plant, the operators experienced significant debris problems which often reduced production and exacerbated difficulties retrieving the eductors. A research effort within the Dredging Research Program was therefore initiated to address the problem of debris clogging which hinders deployment and removal of eductors used in sand bypassing operations.

Additional Information

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Introduction

The DRP work unit "Improved Eductors for Sand Bypassing" was created to design an eductor that maintains good performance in various types of debris and is also more easily deployed and retrieved when used as part of a fixed bypass plant. A number of mechanical and hydraulic devices were considered to solve these problems. The final configuration selected was designed to have the best combination of debris resistance, ease of installation, and simplicity of design and operation. This eductor (hereafter referred to as the DRP eductor) was developed under contract to Genflo America. Included in the contract were requirements for conceptual design, detailed design, construction, controlled comparison tests, and field tests.

Following construction of the DRP eductor, it and another Genflo eductor used at the bypass plant at Indian River Inlet (hereafter referred to as the IRI eductor) were tested under controlled conditions in a gravel pit in both clean sand and with various debris combinations. Test results showed both to have nearly equal performance in clean sand, with the DRP eductor performing better in debris of stones, garbage bags, and swim fins, while the IRI eductor performed better in debris of wood (Clausner, Welp, and Bishop 1993; Clausner and others 1994).

The final part of the DRP eductor development was to perform a long-term field test of the eductor at an existing sand bypassing plant to determine production rates, influence of debris, and deployment capabilities in an actual bypassing operation. The tests were conducted at the bypass plant at Indian River Inlet, Delaware where the IRI eductor is deployed from a crawler crane to mine sand on the south (updrift) side of the inlet. The IRI eductor was designed and manufactured by Genflo America and has nearly identical nozzle, mixer, and diffuser dimensions as the DRP eductor. As such, it provided an excellent baseline for evaluating improvements made in the DRP eductor both in the controlled tests conducted in 1991 and in the tests described in this technical note. Full details of this test and data analysis are included in Williams, Clausner, and Neilans (1994).

Because the DRP eductor was designed with the intention of deployment with a fixed bypass plant, the Indian River Inlet site is not ideally suited to fully test the design features of this cased eductor. The best possible site would have been one with fixed eductors (similar to Nerang) with some debris. No such plant exists in the United States. The bypass plant at Indian River Inlet is neither fixed, nor does it have a significant debris problem. However, the only other U.S. Army Corps of Engineers fixed bypass plant in the United States, located at Oceanside, California, was not compatible with the DRP Genflo eductor requirements for pressure or flow (Moffatt and Nichol Engineers 1990). The Indian River Inlet site did possess a number of attractive features in addition to being the only one suited for this test. First,

the hydraulics (pressure, flow rate, pipeline diameters) were compatible with the DRP eductor. Also, the crane used to deploy the IRI eductor was also capable of deploying the DRP eductor. The level of instrumentation was sufficient for the tests, and the State of Delaware staff overseeing and operating the bypass plant were both skilled and cooperative.

IRI and DRP Eductor Design Features

In the IRI eductor (Figure 1), the nozzle and mixing chamber opening are directly exposed to the ambient surroundings, whereas the DRP eductor (Figure 2) has a smooth, cylindrical outer encasement to prevent debris from jamming in the eductor framework. The IRI eductor's fluidizers are located linearly on a horizontal pipe and direct fluidization water in a divergent pattern. In the DRP eductor, the fluidizing nozzles are located around the perimeter of the DRP eductor and focus the fluidization water at a central point, thereby enabling a more efficient fluidization process. The DRP eductor also contains a "debris grate" over the entrance to prevent debris from entering the suction chamber.

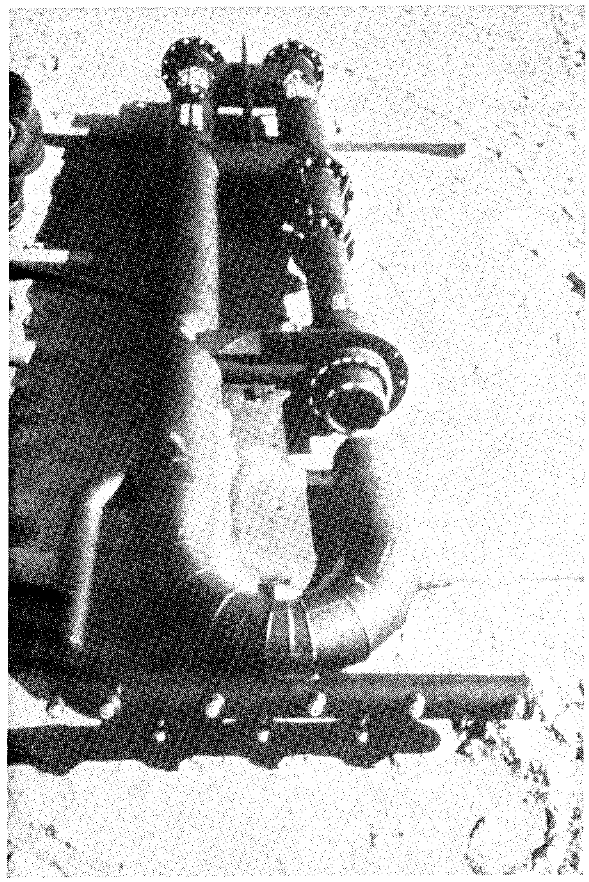

Figure 1. IRI eductor

Both eductors have the same basic hydraulic components. Mixer diameters are identical at 150 mm, and nozzle sizes differ only by 5 mm (65 mm for the IRI eductor and 70 mm for the DRP eductor).

The IRI eductor is designed for use with a crane (Figure 3). The upper end of the eductor connects to a short section of straight pipe followed by a section of curved pipe. The DRP eductor was designed for a fixed plant, and therefore had to be adapted for use during 1991 tests in the gravel pit (Clausner, Welp, and Bishop 1993) and with the mobile crane for these tests. The modifications consisted of a trussed frame designed to hold the eductor at the end of an arched boom, while having rollers on the shoreward end for movement and pivoting. In this case the crawler crane was required only to lift the arched boom containing the eductor. The shoreward end of the frame

Figure 2. DRP eductor

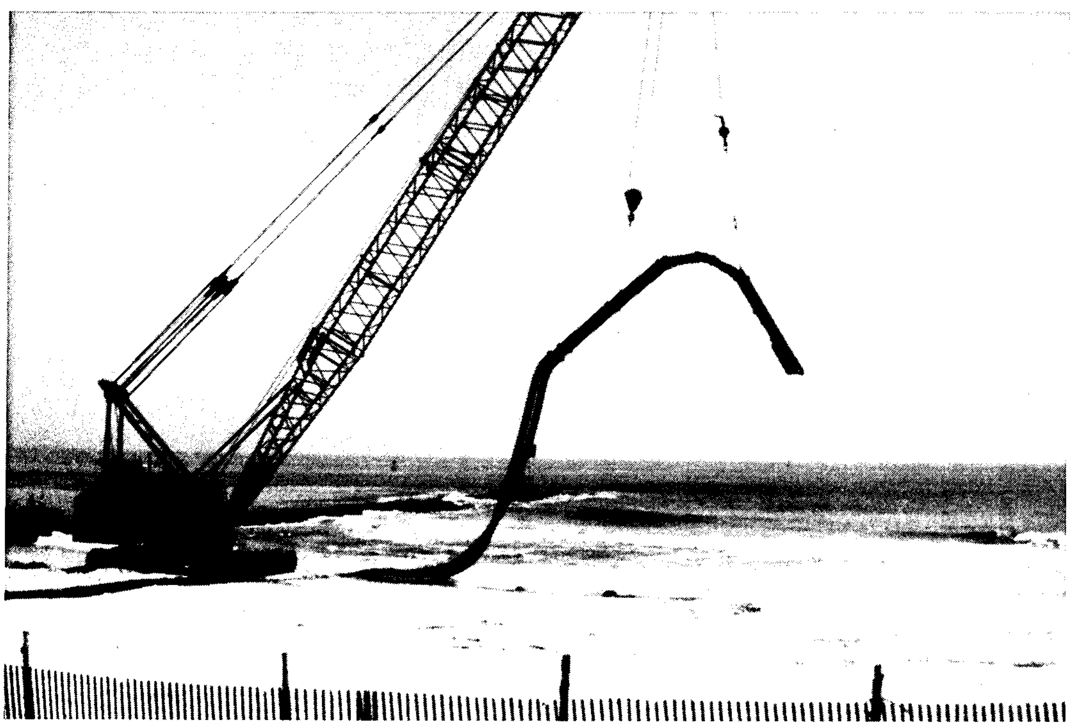

Figure 3. IRI eductor as deployed and operated from the crane

could remain on the beach, and acted as a pivot point for lowering the eductor into the crater (Figure 4). The wide pivot base and arched boom provided increased stability against overturning from crater growth. However, during operations it was found to be easier for the crane to lift the entire trussed frame/arched boom/eductor as a unit and operate it with the roller end completely in the air.

The extra bulk and size of the DRP eductor made it somewhat more difficult to deploy than the IRI eductor. However, this was not a major problem. Unfortunately it was not practical to conduct a real test of the DRP eductor's deployment and retrieval capabilities. This would have required simulating operation from a fixed plant, which entails burying the eductor and performing pullout load tests. These types of tests were performed in the 1991 Louisiana tests. It was not practical to repeat them at this site, nor was it practical to try these tests on the IRI eductor because it was not designed for fixed plant operation.

Site Characteristics and System Operating Procedures

The Indian River Inlet bypass plant consists of an eductor deployed from a crawler crane along a 500-ft-long stretch of beach just south of the south jetty (Figure 5). The supply and booster pumps are contained in a pumphouse located behind the primary dune on the south side of the inlet. The supply pump draws clean water from the inlet and provides it to the eductor through a high-density polyethylene (HDPE) 10-in. supply line. Slurry

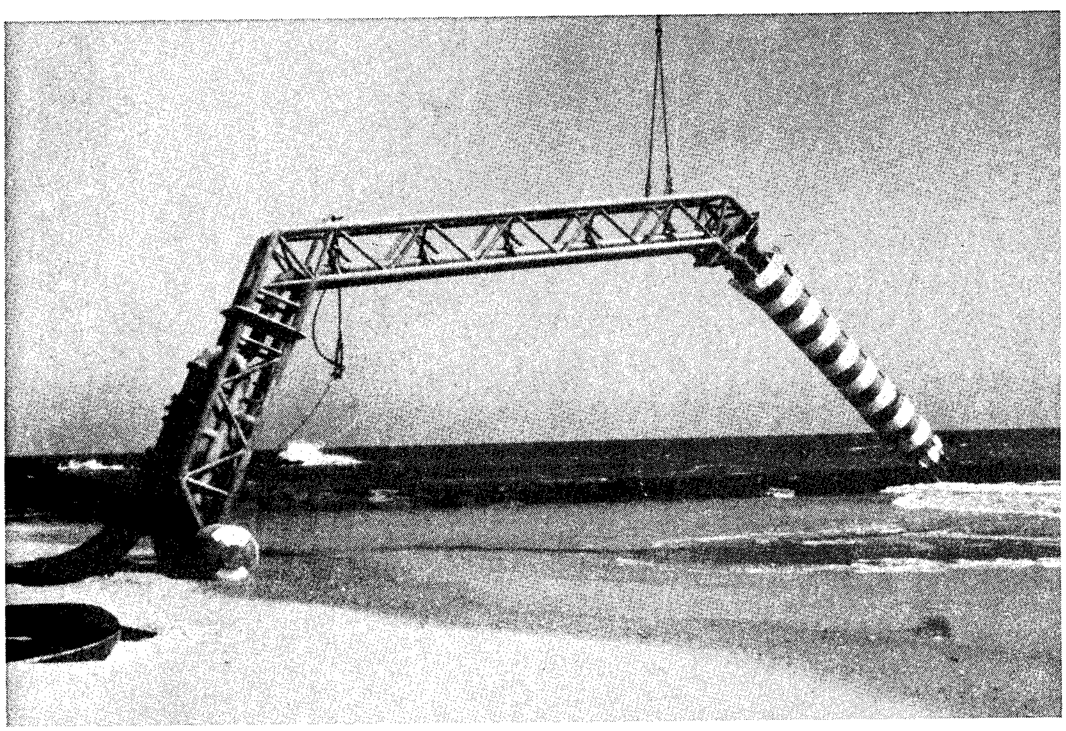

Figure 4. DRP eductor showing rollers and trussed frame/arched boom combination

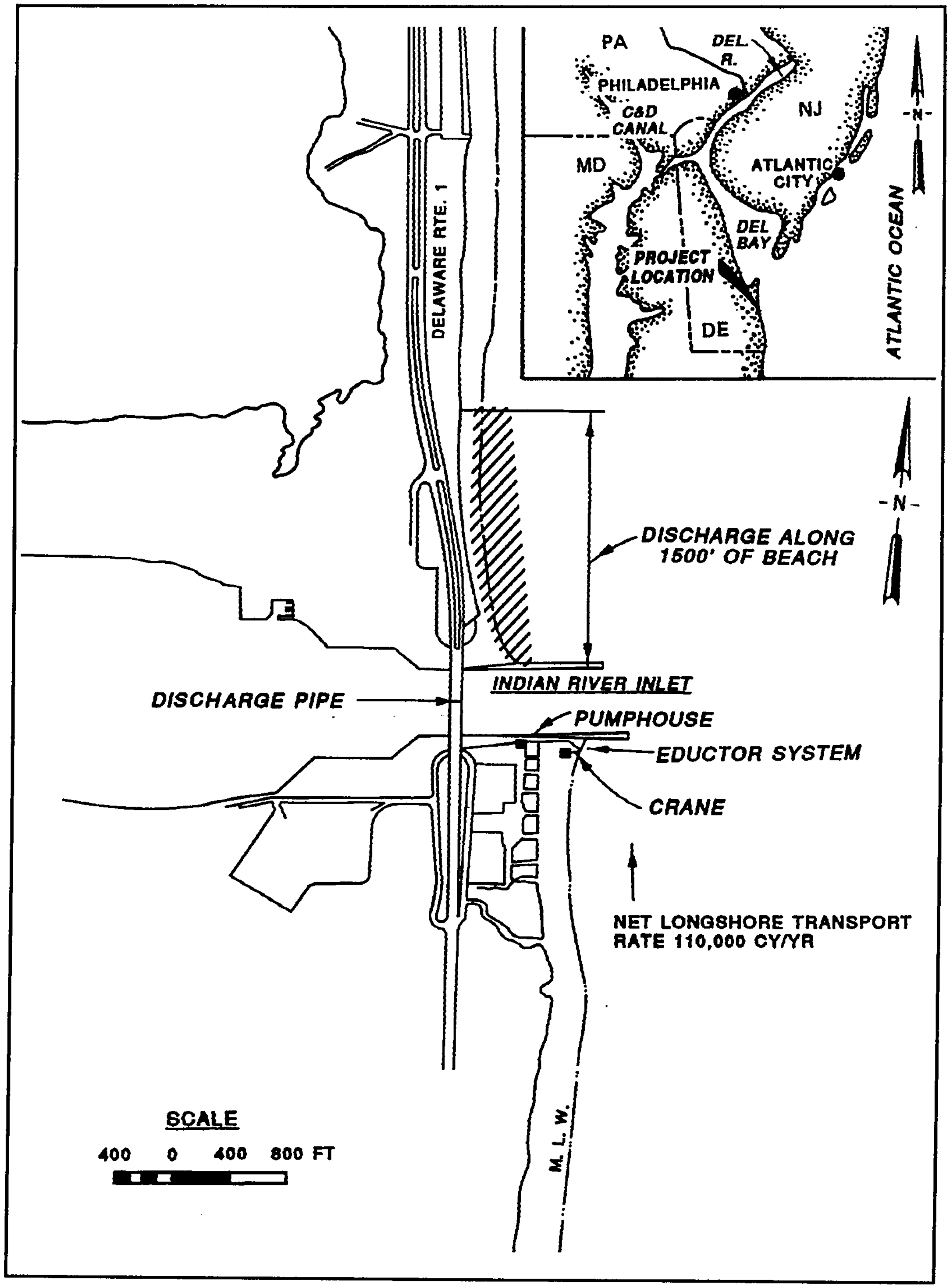

Figure 5. Indian River Inlet site map

discharge from the eductor is pumped to the booster pump via an 11-in. HDPE line. The slurry is then pumped across the Route 1 bridge to the north side of the inlet for a maximum distance of 1,500 ft along the beach. Details of the Indian River Inlet physical conditions, bypass plant system components, and layouts can be found in Clausner, Patterson, and Rambo (1990) and Clausner and others (1991, 1992).

The bypass system requires three persons to operate on a 4 days per week schedule. Bypassing is limited to the period between Labor Day and Memorial Day because of the heavy recreational use of the adjacent beaches during the summer months. Typically, craters approximately 18 ft deep and 48 ft wide (400 cu yd) are created. Generally a trench approximately 150 ft long can be created before requiring movement of the crane. Normal operating procedures were used during the eductor testing period (Clausner and others 1991).

When sufficient sand is available for sand bypassing, the following procedures are normally used by IRI staff. First, the diesels powering the supply and booster pumps and the crawler crane are started and allowed to reach operating temperatures. The crane then moves into position along the shoreline, typically positioning the eductor 30 to 50 ft out into the swash zone. Then the supply pump is engaged, starting the eductor. Next, the booster pump is engaged.

At this point the eductor is lowered into the water and allowed to penetrate the sand down to maximum operating depth, about -18 ft mlw (limited by a peat layer at -20 ft). The eductor typically requires about 1.5 hr to empty the crater. If the combination of tide level and wave activity is sufficient to continue to supply sand at a good rate, the eductor will be left at that location. Generally, after the initial crater is excavated, production is reduced (as indicated on the remote production meter in the crane cab), prompting the crane operator to lift the eductor a few feet and reposition it. Typically, the eductor is moved 10 to 15 ft in a shore-parallel direction, though changes in tide level may also dictate a shore-normal movement. Bypass operations continue throughout the day, until the sand supply is exhausted, the system is shut down for maintenance or to reposition the discharge pipe, or the end of the operating day is reached.

Data Collection Equipment and Procedures

To measure the performance of each eductor, the bypass plant was instrumented to record pressures, densities, and velocities. Pressures were measured at the suction and discharge sides of the booster pump and the motive water supply pump. The density and velocity of the slurry in the discharge line were measured to determine the amount of material being discharged.

All data were gathered using gauges and meters already in place at the bypassing plant to aid in its operation. These gauges and meters were capable of providing (or were adapted to provide) an electrical current

proportional to the gauge or meter reading. A Texas Nuclear density meter, consisting of a radioactive source and a detector located on opposite sides of the pipe, was attached to the discharge line. Immediately downstream of the density meter, an acoustic doppler velocity meter was also mounted on the discharge line.

The pressure, density, and velocity data were recorded using a personal computer equipped with an Analog Devices RTI-815 board capable of transforming up to 32 channels of analog voltage readings into digital data. Each channel was scanned once per second in a burst mode. Thirty-second averages were calculated from the 1-sec scan and written to the output file. Channels 1-8 were used to display and record the slurry velocity, percent solids, production rate, slurry specific gravity, supply pump pressure, booster pump suction, booster pump pressure, and supply pump suction, respectively. Production in terms of in situ cubic yards of material was calculated knowing the density of the sand particles and assuming a 40-percent porosity for the in situ sand. Each day's production, up to the time of each data write, was summed; the accumulated production was recorded as a ninth channel of data. Data for each day of operation were saved in a separate computer file for later analysis.

Data Analysis

The comparison tests were conducted between October 1992 and May 1993. Generally one eductor test run was conducted for each day of bypassing operations. However, on occasion, two test runs were conducted in 1 day when the need for system maintenance caused the bypassing plant to be shut down temporarily (for example, to reposition the discharge pipe). Sixteen DRP eductor test runs were available for analysis from between mid-October 1992 and early February 1993, while 26 IRI eductor test runs were available for analysis between mid-February and mid-May 1993.

Average daily (test run) production rates were calculated for both eductors by summing the accumulated volume (cubic yards) of material bypassed during each test run and dividing by the duration (hours) of pumping for each test run. The calculated average daily production rates (sorted according to duration) are shown for the IRI and DRP eductors in Figures 6 and 7, respectively.

Factors that may have had an impact on eductor performance or influenced comparison analyses were taken into consideration. These factors include test run duration, relative number of test runs for each eductor, booster pump operation method, waves, water levels, and physical and operational parameters of bypass plant. The average daily production rates for each eductor were compared based on these factors and are detailed below.

Test Run Duration. These figures indicate that there is less variability in production for the DRP eductor than for the IRI eductor. Maximum and minimum production rates vary from 428 to 348 cu yd/hr for the DRP

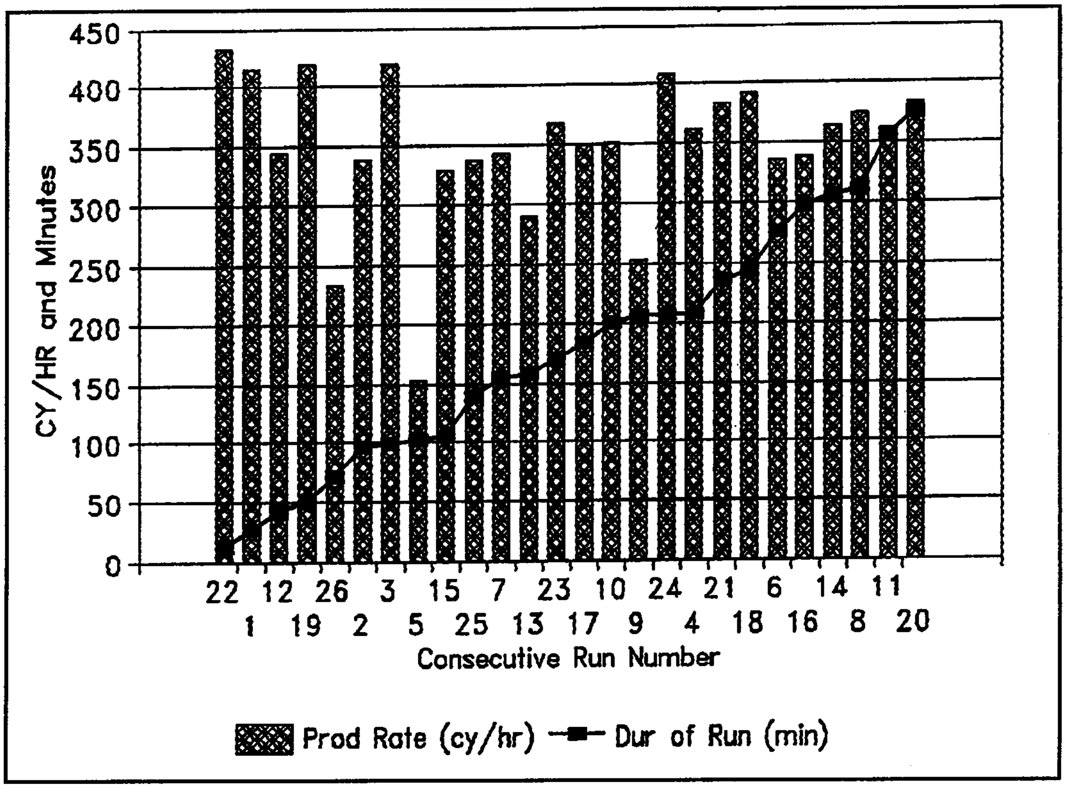

Figure 6. Average daily production rates for IRI eductor (duration sorted)

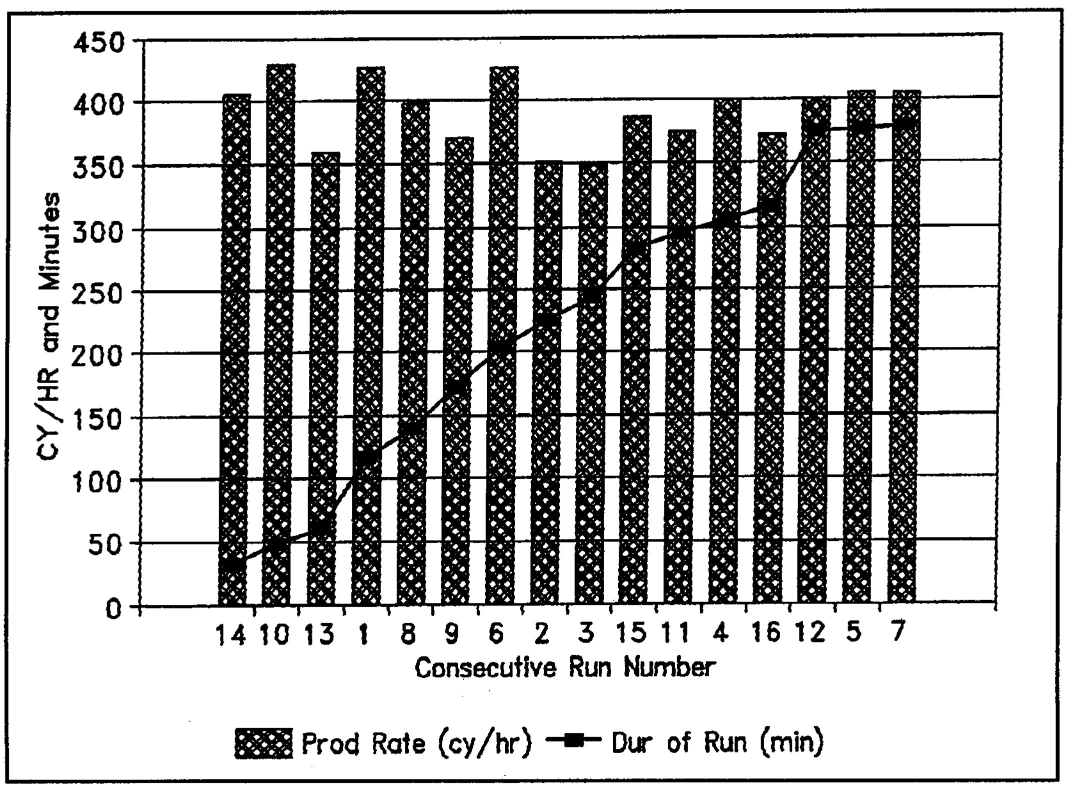

Figure 7. Average daily production rates for DRP eductor (duration sorted)

eductor and from 433 to 153 cu yd/hr for the IRI eductor. When considering all durations, almost all (94 percent) of the DRP eductor production rates are above 350 cu yd/hr, while only half (50 percent) of the IRI eductor production rates exceed this rate. Similar results are found when only the longer durations are examined, those greater than or equal to 250 min (4.2 hr). At these durations, 88 percent of the DRP eductor production rates exceed or equal 350 cu yd/hr as compared to only 50 percent of the IRI eductor production rates.

Number of Test Runs. The difference in the number of test runs for each eductor (16 for DRP and 26 for IRI) could contribute to a statistical bias that may have influenced the analysis. To address this issue, an overall average production rate was calculated for each eductor. This total overall average was determined by dividing the total test run volumes for the DRP and IRI eductors (23,200 and 27,100 cu yd, respectively) by the total duration of operation for each eductor (59.6 and 77.4 hr, respectively). This average results in overall production rates of 389 and 350 cu yd/hr for the DRP and IRI eductors, respectively, indicating an approximate 11-percent increase for the DRP eductor. By normalizing the individual test run production rates by each eductor's respective total average, the production stability of each eductor can be examined. For both eductors, roughly 50 percent of the production rates equaled or exceeded the respective total average production rate, indicating that production stability was similar for both eductors.

Booster Pump Operation Method. The booster pump is the primary force moving the bypass slurry (and also impacts entrainment efficiency). Its consistency of operation could affect eductor production rates. The booster pump was operated by either maintaining constant RPM throughout the pumping cycle or by periodically adjusting the pump RPM to adjust suction and discharge pressure to optimize pumping performance. Without knowing which procedure each pump operator utilized, a comparison of production rates based on operator work schedule was conducted. Booster pump operations varied for each eductor between Operator A, Operator B, or a combination of both operators. A slightly greater variability in production was observed for Operator A with the IRI eductor, but no major trends were observed.

Waves and Water Levels. Waves and water levels during bypassing operations may also have influenced production rates of the eductors by adding sand to the crater either faster or slower depending on the conditions during operation. Water level and wave height data were examined from the Corps' wave gauge located in 30 ft of water approximately 6 miles north of Indian River Inlet at Dewey Beach, Delaware. No discernible differences in production were evident when the production rates for each eductor were regrouped based on the observed wave conditions.

Water levels estimated from the Corps' wave gauge record and supported by National Oceanic and Atmospheric Administration tide tables were used to determine the tidal stage (high, high to low, low, or low to high) for operations during each test run. The DRP and IRI eductors showed the most

consistently large production rates during the rising tides from mid- to high-water through dropping tides from high- to mid-water. Since the eductors performed in a similar manner based on water levels, no differences can be attributed to this factor.

Physical/Operational Parameters. Differences in the overall discharge pipeline length during the course of eductor test runs could have caused differences in production due to increased pressure head requirements. Overall discharge line length was maintained at approximately 1,800 ft for both eductors throughout the testing period. Therefore, discharge pipeline length would cause no differential influences in production.

As mentioned previously, the DRP eductor had a slightly larger nozzle (70 mm) than the IRI eductor (65 mm), which would result in some level of production difference. The DRP's larger nozzle would allow more water to flow, thus creating the potential to entrain more sand. However, it has been suggested that this increase in flow is of negligible impact when compared with the various other influences to which the eductors were exposed. Therefore, although a slight flow difference would have occurred as a result of the physical makeup of the eductors, these differences would have been insignificant.

Conclusions

The eductor field tests described in this technical note were intended to supplement information gained from the controlled eductor tests described in Clausner and others (1994). In this case, actual field operations of a bypass plant with two eductor designs provided the opportunity to determine if significant general performance changes were associated with the design differences. Even though the DRP eductor was specifically designed for a fixed bypass plant with significant debris problems, the nonfixed, low-debris Indian River Inlet bypass plant proved to be a satisfactory test site for production testing. Cooperative plant staff and sufficient instrumentation allowed for an unbiased comparison of these two eductors.

By examining production rates and various influencing factors, the performance of the newly developed DRP eductor was shown to be slightly improved over the existing IRI eductor. Average hourly production rates were calculated to be slightly more than 10 percent higher for the DRP eductor than for the IRI eductor. Other external factors were investigated to ensure that similar conditions existed for both eductor test periods, and no significant influences were identified.

The DRP eductor was somewhat more difficult to deploy than the IRI because it was designed for fixed plant use and was modified for use with the mobile crane by the addition of a roller/truss section/arched boom. Test conditions and equipment at this site did not allow for a good test of the DRP eductor's features to improve deployment and retrieval at a fixed plant.

Recommendations

The selection of an eductor for a particular site will depend on the method of deployment and the type and amount of expected debris. For fixed plants, a cased eductor to prevent wood from jamming in the open framework is recommended for ease of retrieval. Radial fluidizers appear to be a good choice for ease of insertion. The combination of radial fluidizers and the suction chamber design used in the DRP eductor has slightly improved performance over the IRI shrouded eductor. For semimobile plants such as Indian River Inlet, a completely cased eductor is not required. Selection of a shrouded or cased eductor will be more of a trade-off between performance and cost and the ease of servicing it.

The addition of a grate will be a function of the type of debris expected. For stone debris of a size that will not pass through the eductor, a grate is recommended. For wood debris that will pass through the eductor, a grate should not be used.

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